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2 Women and science: Athena Bound

Athena, the Greek mythological figure with strong female and male elements in her identity, personifies the dilemma of the contemporary female scientist. Contemporary female scientists are expected, and often expect themselves, to combine a demanding personal and professional life, without its effects on either. Even as some female scientists struggle to balance their professional and personal lives, others continue or are constrained to comply with a traditional 'male model' that rigidly subordinates the personal to the professional. Women in science comprise a diverse set of persons who, despite a common gender, do not embrace a collective identity.

Many successful women in scientific and engineering professions expect to have crossed a threshold into a work life in which gender is irrelevant. These fortunate few females are taken on as apprentices and, encouraged by their undergraduate professors, enter graduate school in the sciences and engineering. There again, they encounter an opaque competitive system that typically depletes their self-confidence.

Those women who complete the Ph.D. face a series of career choices that often needlessly clash with personal aspirations. As Athena found in pursuing her adventures as a woman in a higher world dominated by a male ethos, gender matters.

Alternate competing theses have been suggested to explain the resistance to women in science. It is not 'either/or'. Rather than 'barriers to entry', visible and invisible impediments to women pursuing a scientific career, or a 'glass ceiling' that places limits on recognition of achievement, difficulties exist at all stages and phases of the scientific career line.

Women who have avoided discouraging experiences at an earlier stage often encounter them later. For example, because women are often excluded from information and informal channels in graduate school, they have less access to 'social capital,' the network of relationships and connections, than their male peers. Without this network of professional and social psychological partners, women of equal or better 'human capital' (their skills and knowledge) are more likely to drop out of graduate school, and those who receive a Ph.D. lack the 'halo effect' that comes from inclusion in such a network.

When a relatively small number of women traverse the pipeline to win a faculty appointment the story is said to have ended successfully. Yet even at this juncture many highly effective women suddenly find themselves subtly ostracized while paradoxically expected to be 'role models' during the precarious tenure process. We call all of these disjunctures aspects of the 'cascade effect' in which the steady flow of energy can be short-circuited at any point, regardless of the level of achievement.

The experiences of women scientists begin and end with the consequences of social exclusion in an activity that necessitates, perhaps demands, community. All too often the consequences of social isolation and aloneness have been attributed to inherent deficits within the women themselves. The argument has been that they lack the right human capital for physically demanding and mathematically intensive scientific work, whether by nature's wisdom which has divided the gene pool or by self-selection into softer fields that permit greater attention to family. However, the experience of separateness and stigma makes more understandable the tendencies for self-blame, lack of self-confidence, fear of risk-taking and role confusion at the highest faculty level. These constraints on women arise from the way that society tracks and awards women and men differently, and are then manifested and reinforced at the organizational level (universities and departments) through discriminatory practices, misperceptions, and social networks that can include or isolate women.

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Female scientists sometimes respond to the strictures against them by adopting a research strategy that emphasizes the careful construction of extensive data bases in a special field rather than rapid shift from one 'hot topic' to the next, longer but less frequent articles, and a reluctance to test hypotheses for fear of being shot down. The barriers to women are such that what appears to be a flawed strategy of reaction actually represents a creative response to obstacles in their path. We have found that in science, these strategies are enacted because the interpersonal networks that promote learning, the practice of the craft, the knowledge transfer, and ultimately the psychological freedom to take the risks inherent in innovative and creative work, are different for men and women. What is paradoxical is that while women pursue the myth that scientific individualism and isolation spurs scientific breakthrough, it is in fact a fiction that undermines their advancements, even as men (and some successful women) operate within networks of collaborative learning that advance ideas most competitively (Powell, Koput and Smith-Doerr, 1996).

SCIENTIFIC HEROINES

Even as they overcame the obstacles in their path, the most successful female scientists were constricted by their gender. The careers of Marie Curie, Lise Meitner, Rosalind Franklin and Rachel Carson provide us with benchmarks of how much has been achieved during the past century and how far the distance to equality was in each of their experiences. Indeed, the entry of women into scientific careers, as more than an anomaly, is a relatively recent phenomenon.

Just a century ago women were barred from seeking degrees and advanced training in the sciences in most universities in Europe. In their youth, during the late nineteenth century, Marie Curie and Lise Meitner received some of their training in so-called 'flying universities' through courses offered in the living rooms of homes by sympathetic male academics (Quinn, 1995). Other, less sympathetic, men believing that women's nature fitted them mainly for family and home, accepted female candidates only under exceptional circumstances, and still others, not at all.

When Lise Meitner emigrated to Germany from Austria to pursue a scientific career, she received financial support from her family that made it possible for her to pursue advanced studies. To Max Planck, the doyen of German physics in the late nineteenth century, Lise Meitner appeared to be one of those exceptional women and he allowed her into his advanced courses and, most importantly, his laboratory, a training experience that an improvised university could not provide (Sime, 1996).

During the nineteenth century women could attend German universities only as unmatriculated auditors. Baden was the first German state to open its universities to women in 1900. Prussia, where Lise Meitner aspired to follow her vocation for physics in Berlin, followed in 1908 and was by no means the last. Perhaps ironically, in the eighteenth century many laboratories, especially in chemistry, had been in kitchens in the home and thus more accessible to women's participation (Abir-Am and Outram, 1986).

The professionalization of the sciences and their incorporation into the universities during the nineteenth century placed the increasingly technologically sophisticated experimental sciences beyond the reach of most interested women. It was not until the 1970s that female access to the laboratory bench again reached the level that it had attained in the eighteenth century, a less institutionalized era in the sciences when upper-class women, at least, had open access to scientific work through their family and social connections (Gabor, 1995). Although women gained formal access to university-level scientific education in the late nineteenth century, informal barriers have persisted into the twenty-first century.

Such barriers are not so obvious as the rule that, even when she attained a research position, restricted Lise Meitner's presence at the Chemistry Institute in Berlin to a makeshift basement laboratory. Despite exclusion from the other laboratories and meeting places of her erstwhile colleagues, Meitner informally guided the investigations

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of male peers such as Otto Hahn through the force of her theoretical insight, combined with careful experimentation. Hitler's persecution finally drove her from her laboratory at virtually the last moment that a person of Jewish background could openly escape from Nazi Germany. Nevertheless, through clandestine contacts, she continued to advise her former colleagues on their research program. Always careful to soothe the male ego, Meitner negotiated a precarious path in German science, contributing at the highest level but receiving recognition at a somewhat lower level than her accomplishments warranted.

Meitner remained an outsider all her life, perhaps most poignantly during her years in Sweden, which provided a haven from Nazi persecution. Although she had a post at a research institute, she lacked access to support staff and research resources. Excluded from the Nobel Prize for the work she did with Hahn, Meitner received fuller recognition only late in life in the form of an Institute named jointly for her and Hahn, several individual scientific awards and a street named after her in Berlin. Nevertheless, she has perhaps only received full recompense from Ruth Sime, her excellent biographer (1996).

Despite the difficulties she encountered, Meitner was the key person in a leading German research center for much of her work life. Nazi persecution, and the war that marginalized Meitner, ironically brought another female scientist to the forefront. Until very late in her professional life, Maria Goeppert Mayer (later a Nobel prizewinner) pursued an outsider career even more on the margins of U.S. academia than Meitner's place in the German research system. Maria Goeppert grew up in an academic family in Göttingen and, when she showed an aptitude for physics, had access to leading scientific figures in the community such as Max Born who became her mentor. Nevertheless, when she married Joe Mayer, an American chemist, and moved to the United States in the early 1930s, her Ph.D. and advanced knowledge of theoretical physics only landed her an unpaid position in the physics department at her husband's university.

With his support and encouragement she was able to pursue a research career at the margins of Johns Hopkins University and then at the universities of Columbia and Chicago (Gabor, 1995). The war-time emergency that drew many women into the workforce also opened up a place for Goeppert Mayer in the Manhattan project, where her previous research meshed with the needs of the crash-program to develop the atom bomb. Until 1959, on the eve of receiving the Nobel Prize, when she left the University of Chicago with her husband to move to the University of California at San Diego, she held no full-time, fully remunerated academic position. She wanted nothing more than to be 'one of the boys,' fully accepted in scientific conversation.

To a great extent she achieved that goal. In discussions in the early 1950s with Enrico Fermi, the Italian physicist then at the University of Chicago, he encouraged her to formulate her ideas and set forth a claim to scientific recognition for her elucidation of the structure of the nucleus. Although she was granted a full academic position only late in life, Mayer can be seen as the prototypical traditional woman scientist, devoted to her work to the virtual exclusion of all other aspects of life. Only through far superior work could she be recognized as an equal.

Mayer's later career coincided with the beginning of the opening up of academic science to women's participation, often through pressures from the Equal Employment Opportunities process. Despite formal, tenured positions achieved by a growing minority of women, the way the world of academic science works still marginalizes women. Nepotism rules that prohibited universities from hiring husbands and wives were only the most overt of the many social and cultural restrictions on women's full participation in academic science. Nepotism rules are gone but reminders that science is a man's world persist even as women strive to make it their own.

In the early post-war era, when a London college's common rooms were still sex-segregated, men could take advantage of scientific women and get away with it by disparaging their femininity. This is how James Watson treated Rosalind Franklin in his autobiographical account, *The Double Helix*. Franklin concentrated on developing a data base of X-ray crystallography photographs to elucidate the structure of DNA but was reluctant to specify a structure until she

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James Watson and his colleague Francis Crick were more willing to put forth speculative hypotheses but they needed access to her data to guide their model building efforts. Watson attempted to wheedle out the necessary information from her without offering collaboration and joint publication, the overt coin of the scientific realm. Rosalind Franklin, the co-discoverer of the chemical composition of DNA, relatively unacknowledged by her male peers and unavoidably passed over by the Nobel Prize committee, owing to her untimely death, had to wait for recognition from her biographer, Ann Sayre.

Rachel Carson, the biologist and author of *Silent Spring*, was widely recognized during her lifetime. However, her fame did not derive from research findings, in the traditional sense, but rather from analytical and literary accomplishments. Carson drew together and synthesized a broad body of evidence on the deleterious effects of chemical production processes and their effluents on the natural environment and human health. Indeed, Carson's own research career was stunted by the social environment of advanced academic science that made it difficult for a woman to find a Ph.D. advisor and be taken seriously as a scholar.

Despite her mother's unstinting encouragement and the availability of a female academic scientist (who herself experienced great difficulties in her research career) as a role model during her undergraduate years, Carson was precluded from a conventional research career by the obstacles she encountered as a graduate student at Johns Hopkins University during the 1920s. Instead, as is still the case for many women who wish to pursue scientific careers, she found a job at the outskirts of conventional science, in her case in a government bureau as a writer of pamphlets on ecology and wildlife.

Collecting the data for her writing projects through field trips and personal observation as well as from sources among a wide variety of researchers, provided the basis for her evocative and precise depictions of *The Sea Around Us* and other ecological themes that combined metaphorical insight and scientific acuity (Lear, 1997). Perhaps ironically, Carson's career on the periphery of science has become an exemplar of a new type of scientific career that emphasizes the relationship between science and society, rather than the traditional pursuit of research in isolation from its uses (Tobias and Birer, 1998).

Science writing, research management, technology transfer and science policy analysis are becoming careers in their own right rather than offshoots of research career lines. As science becomes more important to the political and economic spheres, the career lines that embody these intersections become less exceptional and more important. If traditional practices hold, however, one indicator of the increasing acceptance of such occupational endeavors will be their being taken up by an increasing number of men as well as women. If traditional discriminatory practices persist, the removal of women as leaders, if not practitioners, of these occupations, is also likely to take place.

UNSUNG HEROINES AND INVISIBLE BATTLES

Female scientists often told us, in interviews, about the obstacles that women encounter as they pursue their scientific callings. Academic practices, presumed to be meritocratic and gender-free, often work against women's professional success. These effects are sometimes hidden behind a neutral or even positive facade erected on the publicized achievements of a few exceptional women, some of whom deny the existence of obstacles in their path. Other women are unaware that they have been singled out for negative treatment while still others are all too cognisant but are also wary of challenging unfair practices for fear of reprisal.

Sex-role stereotyping sometimes colors advisor–advisee relationships. There are hidden obstacles, such as the length of the tenure process or the expectation that faculty members should move between schools to broaden academic training, which become apparent when a family or relationship is considered. Overt processes of discrimination include the sexual separation of scientific labor, with men seen as more appropriate to pursue the theoretical aspects of disciplines

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(usually mathematical not experimental) and women as more congruent with the parts of the field related to practice, policy, and the humanities.

The 1997 Harvey award lecture at Rockefeller University unintentionally symbolized some of the continuing gender disparities in science. The Rockefeller ceremony was a typical scientific honorary event in many ways. On the podium, the award recipient in black tie, Leroy Hood, the distinguished molecular biologist and professor of computer studies at the University of Washington, foresaw the union of the biological and computer sciences, and set forth the scientific, technological, commercial and health benefits that would issue from this marriage of disciplines. Curiously, even though Rockefeller University has a number of female faculty and graduate students, and the biological sciences have for some decades attracted a steadily increasing number of women, Dr Hood's formally attired cohort of hosts were all men.

Invidious distinctions, such as differences in timing, even appear in seemingly positive experiences such as the receipt of rewards. When a woman receives a prestigious fellowship or award, too often it comes late in her work life when it does not provide the same career boost as it would have at an earlier stage.

Cultural traits that are helpful to the conduct of science as well as those that are discriminatory must be disentangled from their origins in order to create a gender-neutral scientific role and workplace. The sexual separation of labor, the association of certain occupational specialties with one gender or the other strongly persists in most societies.

Perhaps ironically, the gender associated with a particular field may reverse, suggesting that the association is hardly inevitable. For example, nursing, a male occupation well into the nineteenth century, had become a largely female field not long into the twentieth century. The profession also, along the way, acquired the presumption of 'natural' association with the traditional feminine trait of nurturance. Those males who continued to enter the profession disproportionately assumed high-level positions, reflecting the continuing association of traditional male characteristics with leadership (Etzkowitz, 1971).

ECONOMIC AND STRUCTURAL BARRIERS

The state of the economy also affects conditions of entry and retention of women in science. Barriers to entry in industry and academia fall most easily under conditions of expansion and prove more intractable under conditions of recession. In the United States, Finland, and Portugal, women gained an increased proportion of R&D (research and development) positions during the post-war expansion of the sciences (Ruivo, 1987) On the other hand, when the expansionary period ended in Finland in 1983, it became more difficult for women, relative to men, to obtain posts in academic science. During such periods of increased competition, 'informal discriminatory practices and attitudes...' take hold with renewed strength (Luukkonen-Gronow, 1987: 196).

The renewal of discriminatory practices under harsh economic conditions can best be avoided if enough women have attained decision-making positions in science and technology workplaces by the time the downturn occurs. Otherwise, a disproportionate number of women ' . . . will lose their positions . . . unless preventive measures are devised' (Ruivo, 1987:390). Even when they retain their positions, a disproportionate number of women are to be found on the lower rungs of the job ladder in many scientific and engineering organizations.

OVERCOMING RESISTANCE TO WOMEN IN SCIENCE

Despite often having to put up a brave front in order to gain acceptance from their male peers, successful women scientists as well as other female professionals are becoming more willing to acknowledge the greater burden that they carry as women, and to seek changes in career structures and work styles. In an era of financial stringency and increased research competitiveness, change is made more difficult by pressures to obtain grants and lengthen one's list of publications. On the other hand, the struggle for equality is eased somewhat by allies

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among younger male scientists seeking some of the same reforms, to allow a better balance between their personal and professional lives.

Women scientists and academics, individually and collectively, are taking a more aggressive approach to redressing the imbalances between male and female participation, especially at the upper reaches of academia. Several generations of alumni of Radcliffe College are engaged in an organized effort to get the administration of Harvard University to increase the extremely low numbers of women with higher-level academic appointments at the university, including in the sciences. They have established an escrow fund to encourage donors to put their gifts on hold until progress is made.

The technical advisor to this effort is Dr Lily Hornig, a physicist and long-term activist on behalf of women in science. The perpetuation of gender-linked work roles and the continuing low rate of participation of women in many scientific disciplines appears to contradict one of the accepted standards of science: the norm of 'universalism', or in other words, the principle that scientific careers are open to all who have talent. The norm of universalism, formulated by sociologist Robert K. Merton, is that the acceptance or rejection of claims should not be based upon 'the personal or social attributes of their protagonists' (1973 [1942]: 270). It suggests that although science has traditionally been a male-dominated profession, it is not inherently so.

Moreover, by excluding persons of talent, as Merton argues in his analysis of the scientific profession in Nazi Germany, science is diminished by a 'racialist purge' (Merton, 1973 [1938]: 255). Although not as immediately striking as the elimination of Jewish scientists from German universities in the 1930s, the long-term relative exclusion of women has had a similar hampering effect on the conduct of science.

An earlier body of research identified as fallacious the notion that advancing age inevitably inhibited high-quality scientific work (Merton and Zuckerman, 1976). Unwarranted presumptions that youth was associated with high scientific achievement had served to justify extreme work pressures in early career stages. These unduly heightened expectations for early achievement have had unintended consequences on women's participation in science, given their coincidence with child-bearing years. Nevertheless, the implications of this earlier research for the structure of scientific careers, and the leeway for possible restructuring, has yet to be taken fully into account. We view these issues as 'critical transitions,' a series of overt and covert points in the life course when individuals are either propelled forward to careers in science or deflected away.

THE CONFLICT BETWEEN THE PERSONAL AND THE PROFESSIONAL

During their early childhood years, boys and girls develop different gendered images of scientists and what they do. Despite some early negative perceptions, large numbers of girls express interest in science and many follow up this interest through coursework and extra-curricular activities, often with the encouragement of teachers and parents. When they enter U.S. universities young women are disproportionately removed from science and engineering majors by a harsh 'weed-out' system designed to test the mettle of young males, well socialized in the norms of competition. Nevertheless, some women, looking back, report a positive experience of being mentored as undergraduates.

Despite the increased entry of women into science, opposition to their full participation continues. Implicitly 'male' standards of behavior permeate scientific time and space, including a belief that a researcher is most productive when their time is devoted to investigation to the virtual exclusion of all other aspects of life.

Ironically, the personal qualities required for success in science may be changing. Sociability, a trait traditionally associated with women, has also been found to be conducive to success in science, especially as the individual researcher is supplanted by group research, and multiple-authored publications become the norm. Perhaps, in the future, female socialization will become a career advantage in the scientific and engineering professions.

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At present, female social attributes are a disadvantage that is exacerbated by competitive norms. While scientific training is an arduous process for all, our research and that of others suggests that women who aspire to scientific careers face barriers that do not equally exist for men and that equal success results only from truly heroic efforts (Abir-Am and Outram, 1987).

A letter to the editor of *The New York Times* entitled 'Science is for Childless Women' (May 17, 1995) exemplifies the persisting dilemma of women in science. The writer, Stephanie Dimant, identified herself as '. . . one of those women who "leaked out of the pipeline"'. She cited the difficulty of reconciling the hours required of a bench scientist with the demands of raising a family. In a fast-paced, high-pressured environment, traditional solutions such as withdrawing from research for several years to raise a family and returning later were 'so unrealistic as to be comical.'

In bench science, '. . . no second prizes are awarded, and the economic situation demands unrelenting writing of grant applications and publication of results.' Diment could not think of anyone she knew who had taken the extended leave option and who later returned to the academic track. Female scientists who made the decision to combine an academic career with raising a family typically took only the briefest time off for having a baby and then spent their limited maternity leave '. . . with an infant in one hand and a telephone connected to the lab in the other.' Nor will there be many protests: given the stringency of research funding and the paucity of academic jobs, women do not want to be labelled as 'lame ducks'.

Nevertheless, given the pressures on women, including those that force the lower-paid spouse (rarely a man) to assume primary responsibility for child care, 'It is not surprising that many eventually make a heart-wrenching decision to leave bench science to those who have no children or to those who are fortunate to have that acknowledged asset, a wife.' Despite these obstacles, some women with children attain the highest levels of scientific achievement and recognition.

However, the price of success appears to be significantly related to each woman's ability to adapt to the highly competitive milieu of science. Dr Shirley Tilghman, director of a 'large and wildly successful' laboratory at the Howard Hughes Institute of Princeton University, concluded, 'Maybe it's because I've been in science so long that competition just seems like life. Maybe I've just given up.' A competitive sports enthusiast as a child, Dr Tilghman, a Canadian citizen and a recently elected foreign associate of the U.S. National Academy of Sciences, was featured in an article in *The New York Times* 'Fighting and Studying the Battle of the Sexes With Mice and Men.'

The article discusses Dr Tilghman's research on genetic imprinting, her experience as a mother and her concerns about the future of women in science. She is described as having 'jury rigged the pieces of her life by being almost preternaturally organised and focused, as well as spiritedly fierce in her work', in contrast to many women who draw back when criticized. Although she raised her two children as a single parent for most of their childhood, the article did not detail the child-care arrangements that made this possible.

Her own female graduate students were highly skeptical of their ability to follow her example, fearing, like Ms Dimant, that they would be forced to choose between science and motherhood. The students told Tilghman, 'Don't tell me about your experience. Your experience has no bearing on me.' They feared the time pressures of a highly competitive research funding system as well as the accepted belief that constant presence in the laboratory is a prerequisite for scientific success. Is there a one-to-one relationship between time put in and results achieved? Dr Tilghman attempted to reassure her students that '[h]ow one does in science is really dependent on your creativity and originality, and not how many mini-preps you can do in a 24-hour period', but the students were not convinced.

Unsure that this assessment applied to them, the students believed that the grant environment, now more competitive than their mentor had faced as a young scientist, inevitably increased the time that had to

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be devoted to a scientific career. Although a competitive environment also affects men, increased time pressures have additional effects on women. Thus, even this notable success story of a woman's achievements at the highest levels illustrates the persisting dilemma of women in science. This dilemma has its roots in the earliest years of childhood, and our next chapter focuses on how gender socialization affects the entry of girls and boys into scientific careers.